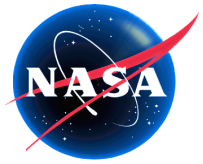

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Advanced Remote-sensing Imaging Emission Spectrometer ARIES

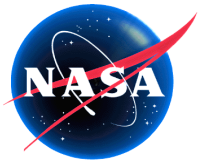
A Global Earth System Science Instrument Concept

Science Benefits and Technical Approach

T. Pagano, M. Chahine, A. Gerber

Jet Propulsion Laboratory

March 7, 2007



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ARIES is an instrument concept that builds on MODIS and AIRS

- Advanced Remote-Sensing Imaging Emission Spectrometer
- ARIES based on MODIS and AIRS but with greatly enhanced capability: uses new technology.
  - Hyperspectral (3.4 – 15.4 μm)
    - Higher spectral resolution than AIRS
  - Higher Spatial Resolution
    - IR (1km vs 13.5 km on AIRS)
  - Global Coverage
    - Scans ±55°
  - High Calibration Accuracy and Stability for Climate
- ARIES Technology Ready for Flight!

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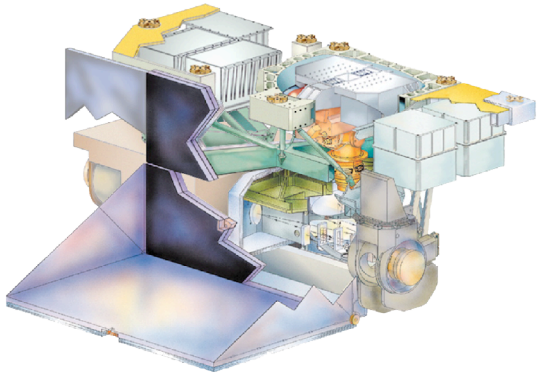
ARIES Combines AIRS and MODIS IR Measurements into One System

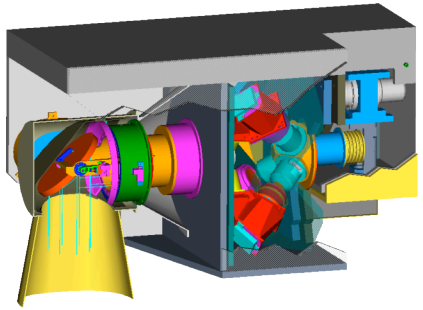
Improved:
- **Horizontal Resolution**
- **Spectral Resolution**
- **Product Accuracy**

AIRS High Spectral



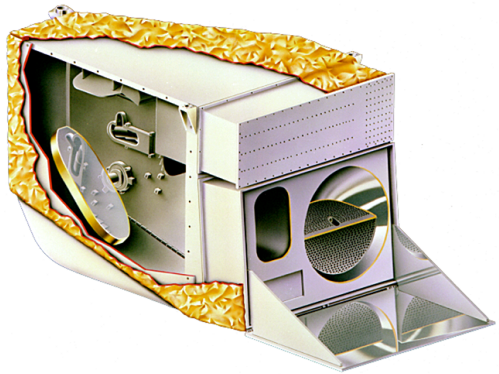
AIRS
- 13.5 km IR IFOV
- 3.7-15.4 μm IR
- 2378 IR Channels
- $\lambda/\Delta\lambda$ = 1200
- NEdT = 0.05 - 0.3 K
- ± 50° FOV

High Spatial / High Spectral



ARIES
- 1 km IR IFOV
- 3.4-15.4 μm
- >3000 Channels
- $\lambda/\Delta\lambda$ > 1000 (IR)
- NEdT = 0.1 - 0.3 K
- ± 55° FOV

MODIS High Spatial



MODIS
- 1 km IR IFOV
  0.25-0.5 km VNIR/SW
- 0.4-14.2 μm IR
- 20 RSB, 16 IR Channels
- $\lambda/\Delta\lambda$ = 20-50
- NEdT = 0.05 - 0.3 K
- ± 55° FOV

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ARIES Planned Improvements

- Improved Weather Predictions
  - Improved Boundary Layer Sensitivity
  - Essential for future high spatial resolution weather models (fvGCMs)
  - Surface Spectral Emissivity at 1km Resolution
  - Improved 3D water vapor winds in polar regions
  - Greatly Improved Regional Weather Prediction
  - Hurricanes: Improved track and intensity prediction
  - Tornados: First ever satellite observation and prediction through high resolution observations
- Improved Climate Model Validation
  - Relate regional scale processes to global scale models
  - ARIES Measures Primary greenhouse gases: H_2O, CO_2, CH_4, CO, O_3
- Natural Hazards and Applications
  - Image gases from fires as well as smoke
  - Improved volcano SO_2 plume detection and tracking.
  - All MODIS applications + Gases at 1km spatial resolution

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ARIES Primary Products

- What's New
  - High spatial resolution gases and water (2km vs 50 km now)
  - Hyperspectral detection and classification
  - Improved Boundary Layer Sensitivity
- Products
  - Temperature and Water Vapor Profiles
  - Surface Emissivity and Temperature
  - Composition Profiles: O_3, CO, CO_2, CH_4, SO_2 (Boundary layer to Upper Troposphere)
  - Aerosol Properties
  - Cloud Microphysical Properties
  - Outgoing Clear and Cloudy Longwave Radiation

- Vis/NIR/SWIR Option (or Possible 2nd instrument)
  - Enhanced Vegetation Index, LAI/FPAR
  - Hyperspectral BRDF/Albedo
  - Land Cover Change
  - Ocean Color Products

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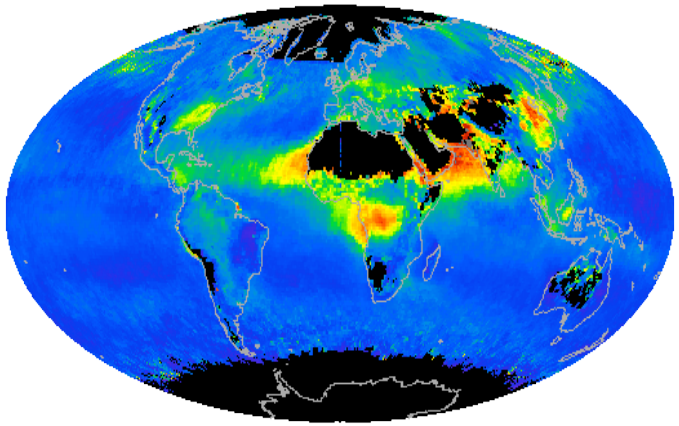
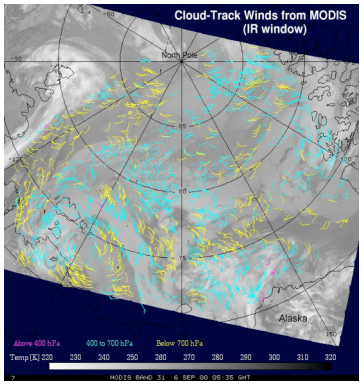
MODIS Products Improved with ARIES

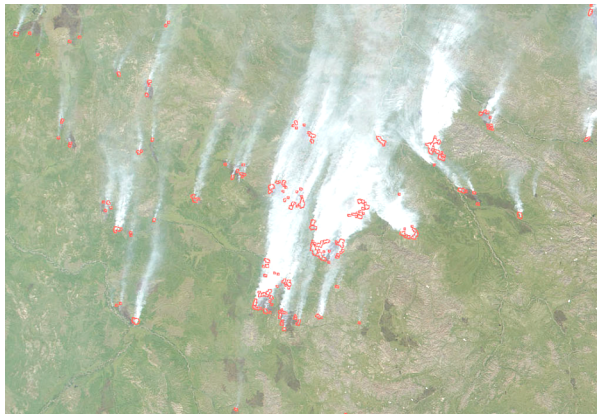
Aerosols



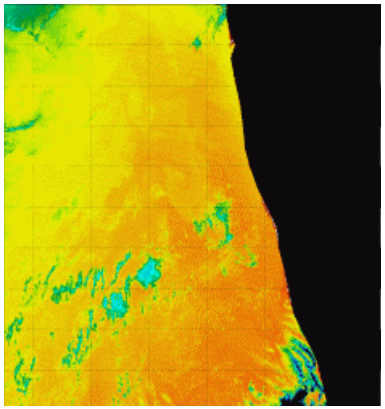
Polar Winds



Fires

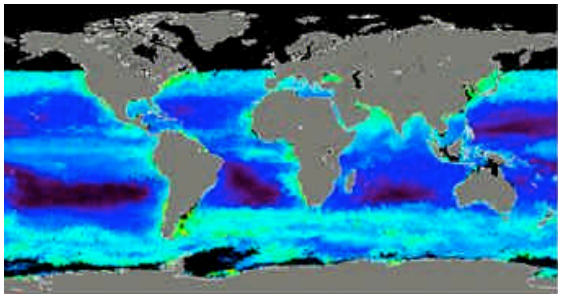


SST



Optional

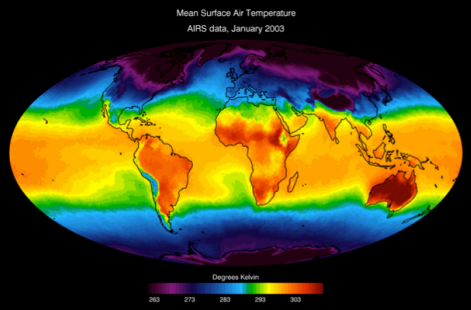
Ocean Chlorophyll



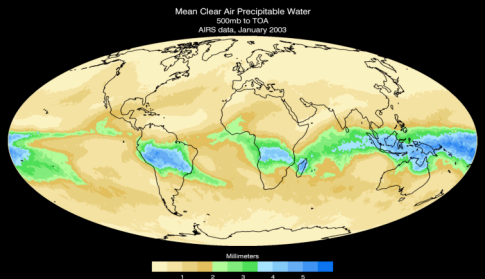
ENDVI

AIRS Products Improved with ARIES

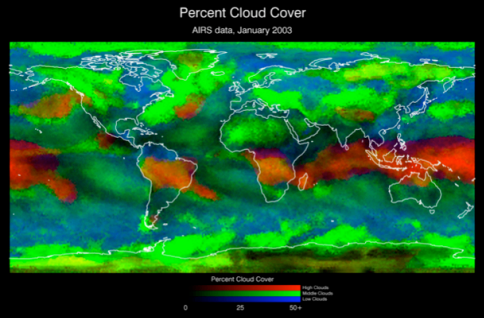
Atmospheric Temperature



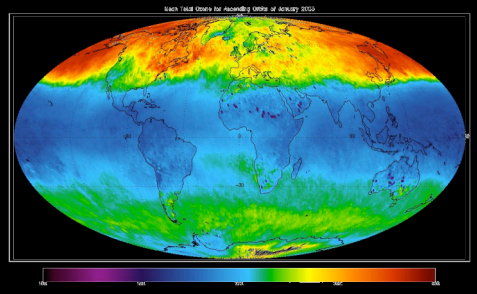
Atmospheric Water Vapor



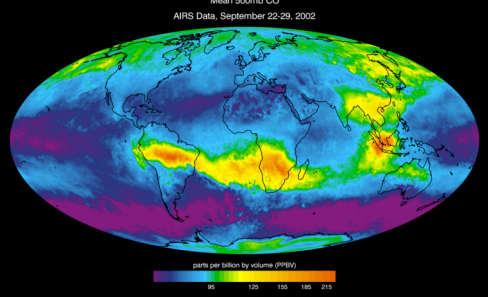
Cloud Properties



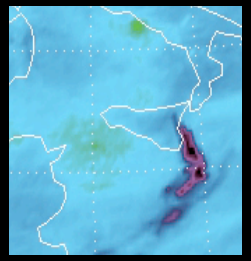
Ozone



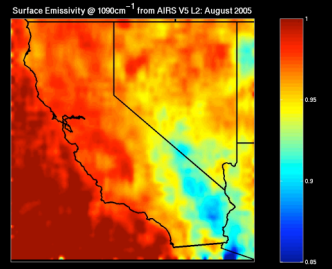
CO



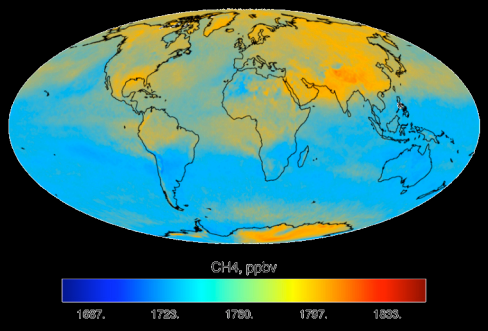
SO2



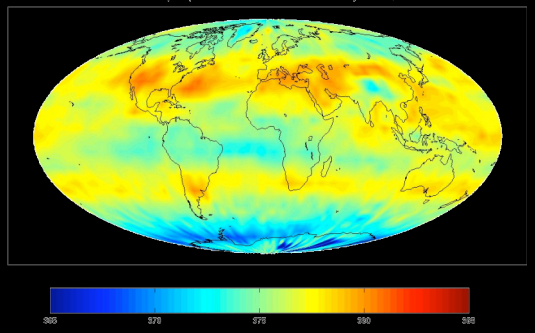
Emissivity



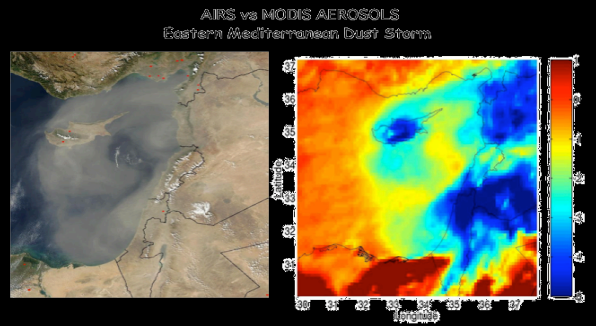
Methane



CO2



Dust



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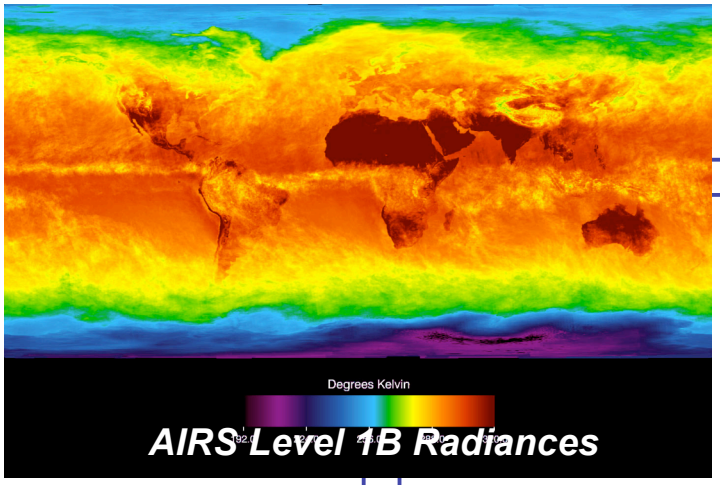
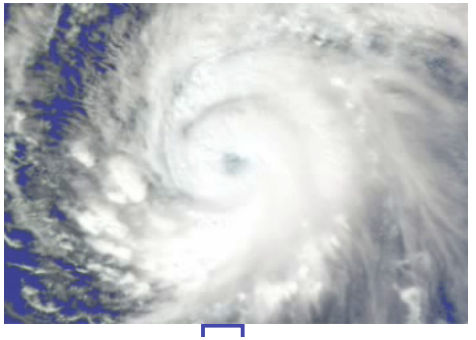
ARIES will follow AIRS in Support of NWP Centers and Regional Forecast Centers



GSFC/ DISC

Near Real Time Product Generation



3D Temperature and Water Vapor Profiles

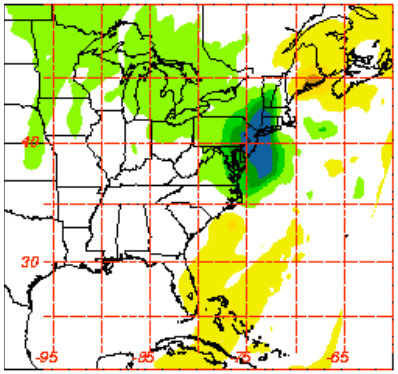
Near Real Time Assimilation

Regional Forecast Centers

SPORT

NCEP, ECMWF, and UKMet Operational Forecasts

6 Hrs on 6 Day Improvement on Operational NCEP Forecast



Over 4 hPa Improvement in Regional Model Forecast

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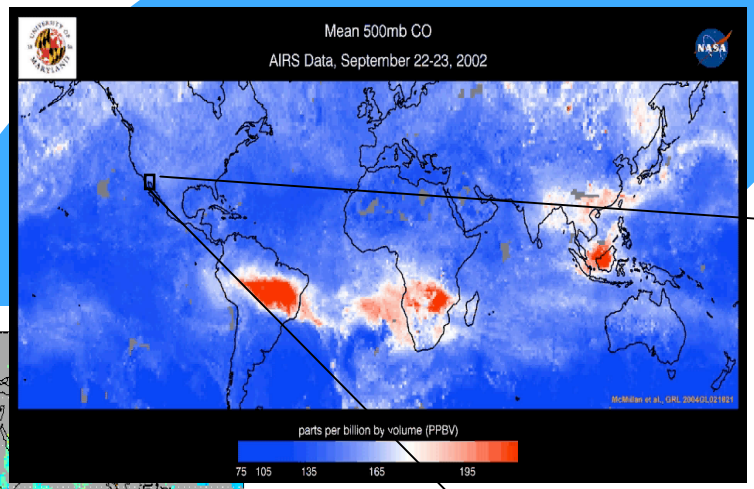
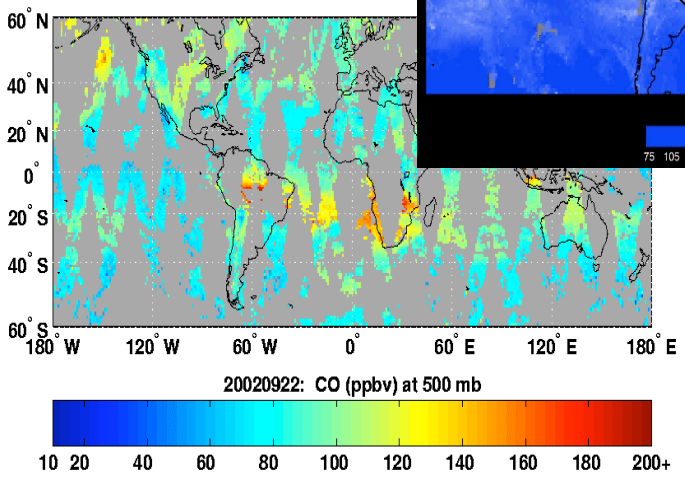
ARIES Brings NASA Global Science Investigations to a Regional Scale

Global Carbon Monoxide Observations
Past, Present and Future

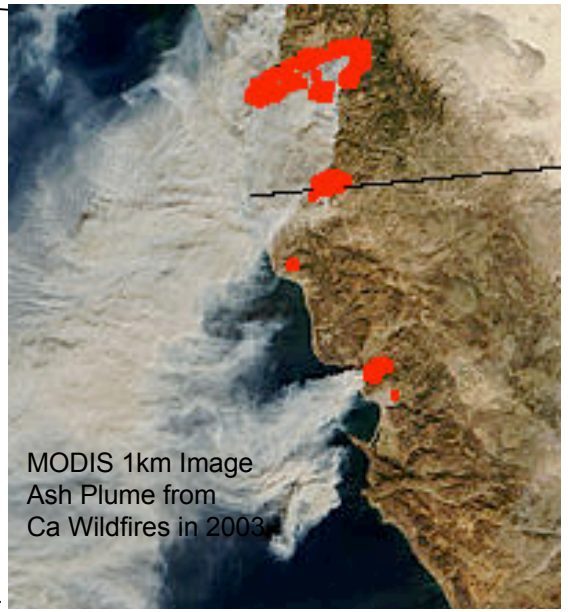
Current: AIRS, Grating, 15 km IFOV Daily Global

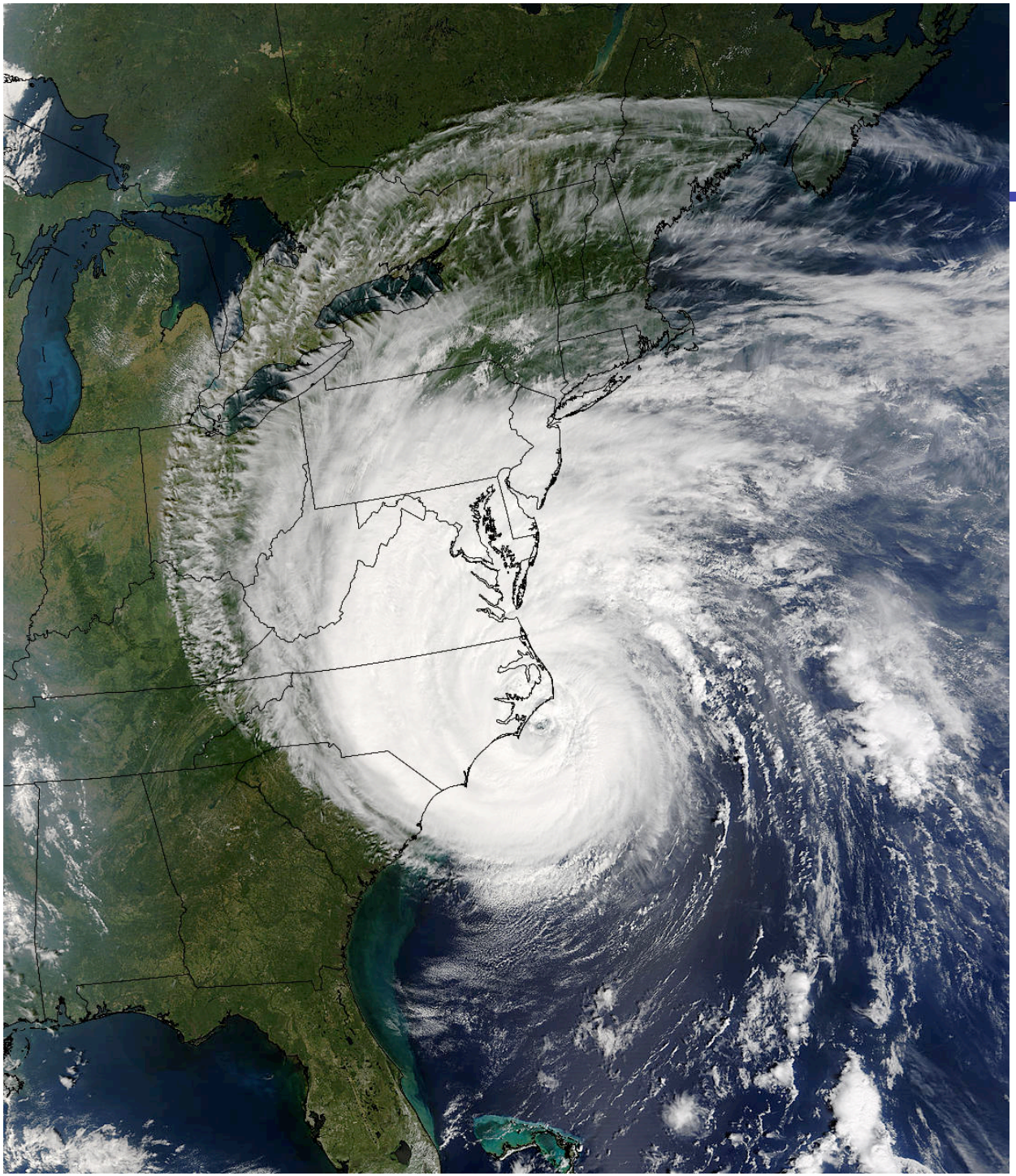
Past
MOPITT
Gas Cell
22 km IFOV
Monthly Global





Future
ARIES
1 km IFOV
Regional Coverage





ARIES will bring High Spatial Resolution to Infrared Sounding

MODIS
Hurricane Isabel
Dec 10, 2002

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Relation to NPP and NPOESS

- ARIES Measures Key EDRs
  - Consistent with VIIRS, CrIS and OMPS
  - Exceptions
    - No Constant Resolution (VIIRS)
    - No Low-light-level Imagery (VIIRS)
- Provides higher spatial resolution and hyperspectral for advanced new Capability
- Provides several P^3I Products at high spatial resolution
  - CO, CH_4, CO_2
- Can synthesize response of MODIS, VIIRS, AIRS or CrIS for direct cross comparison

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NPP and NPOESS C1 EDR's Met by ARIES

★ **- Addressed by ARIES**

★ Atm Vert Moist Profile	★	
★ Atm Vert Temp Profile	★	
★ Imagery	★	
★ Sea Surface Temperature	★	
★ Sea Surface Winds	⊘	
★ Soil Moisture	⊘	
Aerosol Optical Thickness	★	
Aerosol Particle Size	★	
Aerosol Refractive Index	⊘	
Albedo (Surface)	★	
Auroral Boundary		
Auroral Energy Deposition		
Auroral Imagery		
Cloud Base Height	⊘	
Cloud Cover/Layers	★	
Cloud Effective Part Size	★	
Cloud Ice Water Path	⊘	
Cloud Liquid Water	⊘	
Cloud Optical Thickness	★	
Cloud Particle Size/Distrib	★	
Cloud Top Height	★	

Cloud Top Pressure	★	
Cloud Top Temperature	★	
Down LW Radiance (Sfc)	★	
Down SW Radiance (Sfc)	★	
Electric Fields	⊘	
Electron Density Profile	⊘	
Energetic Ions		
Geomagnetic Field	⊘	
Ice Surface Temperature	★	
In-situ Plasma Fluctuation	⊘	
In-situ Plasma Temp	⊘	
Ionospheric Scintillation	⊘	
Med Energy Chgd Parts		
Land Surface Temp	★	
Net Heat Flux	★	
Net Solar Radiation (TOA)	★	
Neutral Density Profile	⊘	
Ocean Color/Chlorophyll	★	
Ocean Wave Character	⊘	
Outgoing LW Rad (TOA)	★	
O_3 – Total Column Profile	★	

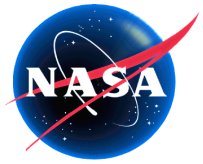
Precipitable Water	★	
Precipitation Type/Rate	⊘	
Pressure (Surface/Profile)	★	
Sea Ice Characterization	★	
Sea SFC Height/TOPO	⊘	
Snow Cover/Depth	⊘	
Solar Irradiance	⊘	
Supra-Therm-Aurora Prop		
Surface Type	★	
Active Fires (Application product)	★	
Surface Wind Stress	⊘	
Suspended Matter	★	
Total Water Content	★	
Vegetative Index	★	

LEGEND

VIIRS (24)	⊘ GPSOS (2)
⊘ CMIS (19)	CERES/ERBS
CrIS/ATMS (3)	⊘ TSIS (1)
OMPS (1)	⊘ ALT (3)
SES (13)	⊘ APS (4)

★ - Key Performance Parameters

⊘ **- C2 or Descoped**



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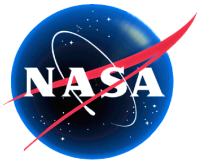
Technical Approach



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ARIES Channel Specifications and Resolution

	Option		**Baseline**			
	Vis/NIR	SWIR	**MWIR1**	**MWIR2**	**LWIR**	**VLWIR**
λ_{min} (um)	0.40	1.22	3.39	6.20	8.70	11.36
λ_{max} (um)	1.00	2.18	4.76	8.70	11.36	15.38
ν_{max} (cm^{-1})	10000	4587	2100	1150	880	650
ν_{max} (cm^{-1})	25189	8197	2950	1613	1150	880
$\lambda/\Delta\lambda$	146	441	2227	2585	1887	1552
$\Delta\lambda$ (nm), $\Delta\nu$	4.8	3.9	1.1	0.5	0.5	0.5
Nchan	254	254	787	999	637	674
IFOV (km)	0.25	0.50	1.00	1.00	1.00	1.00
SNR/NEdT	120-210	50-120	0.15K	0.3K	0.3K	0.5K

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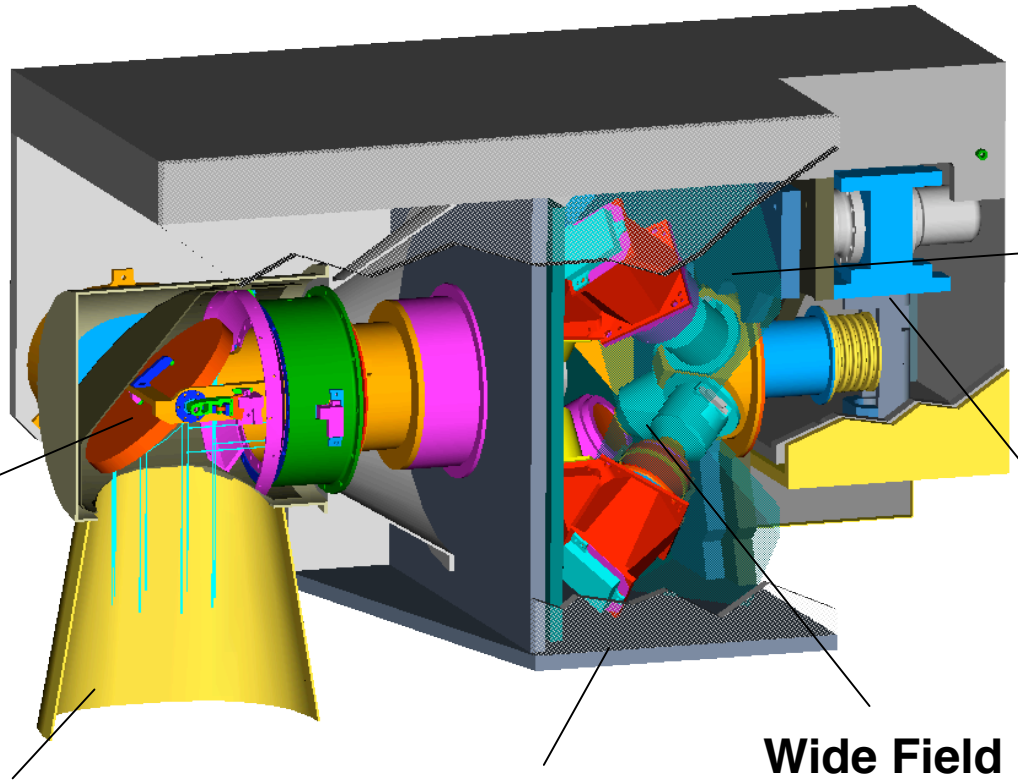
ARIES Baseline Concept

Size: 0.5 x 0.5 x 1.0 m
Mass: 150 kg
Power: 200 W



Thermally Isolated & Controlled Optical Bench

Scan Mirror

Active Cryo-Cooler

Sunshade

Passive Radiator

Wide Field Spectrometers And FPAs

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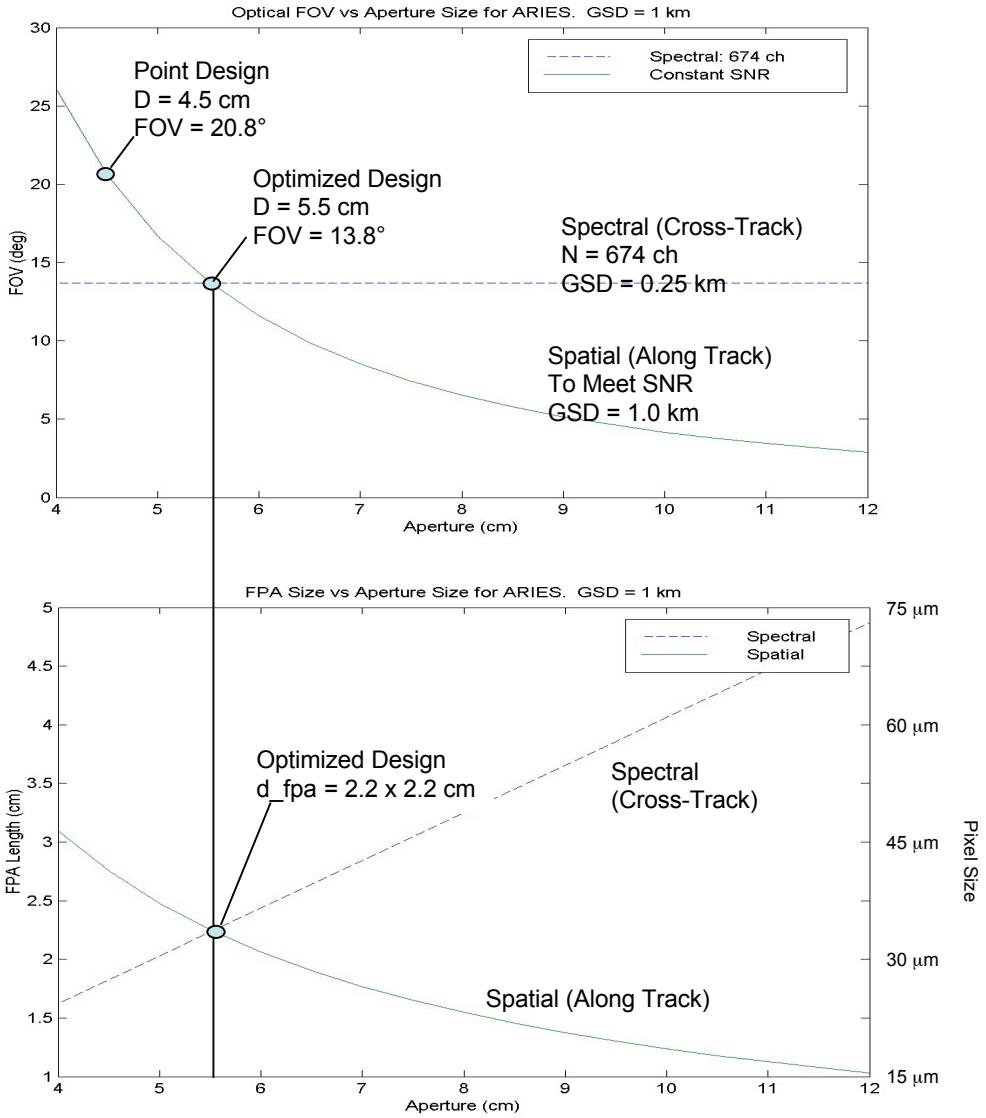
Small Change to Point Design will Allow Symmetric FOV and FPA

ARIES Tradeoff
FPA Size and Optics FOV vs System Aperture
1km IFOV, 705 km Orbit
F# = 1.7

- Increase Aperture by 1 cm
- Reduce FPA Size Along Track Spatial
- Increase FPA Size Spectral Direction



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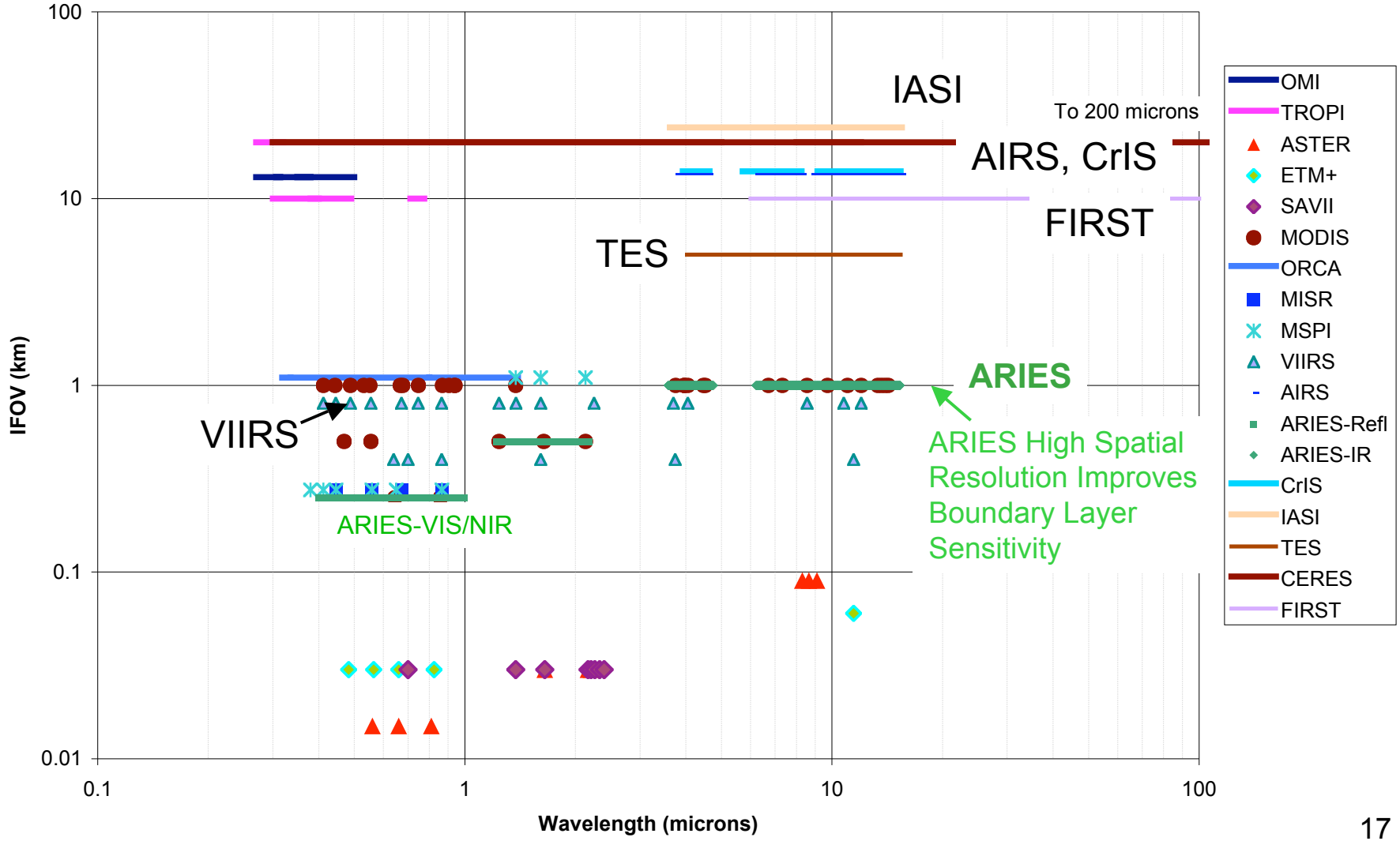
ARIES Has Higher Spatial Resolution than Current and Future Sounders

Spatial Resolution For Spaceborne Optical Sensors



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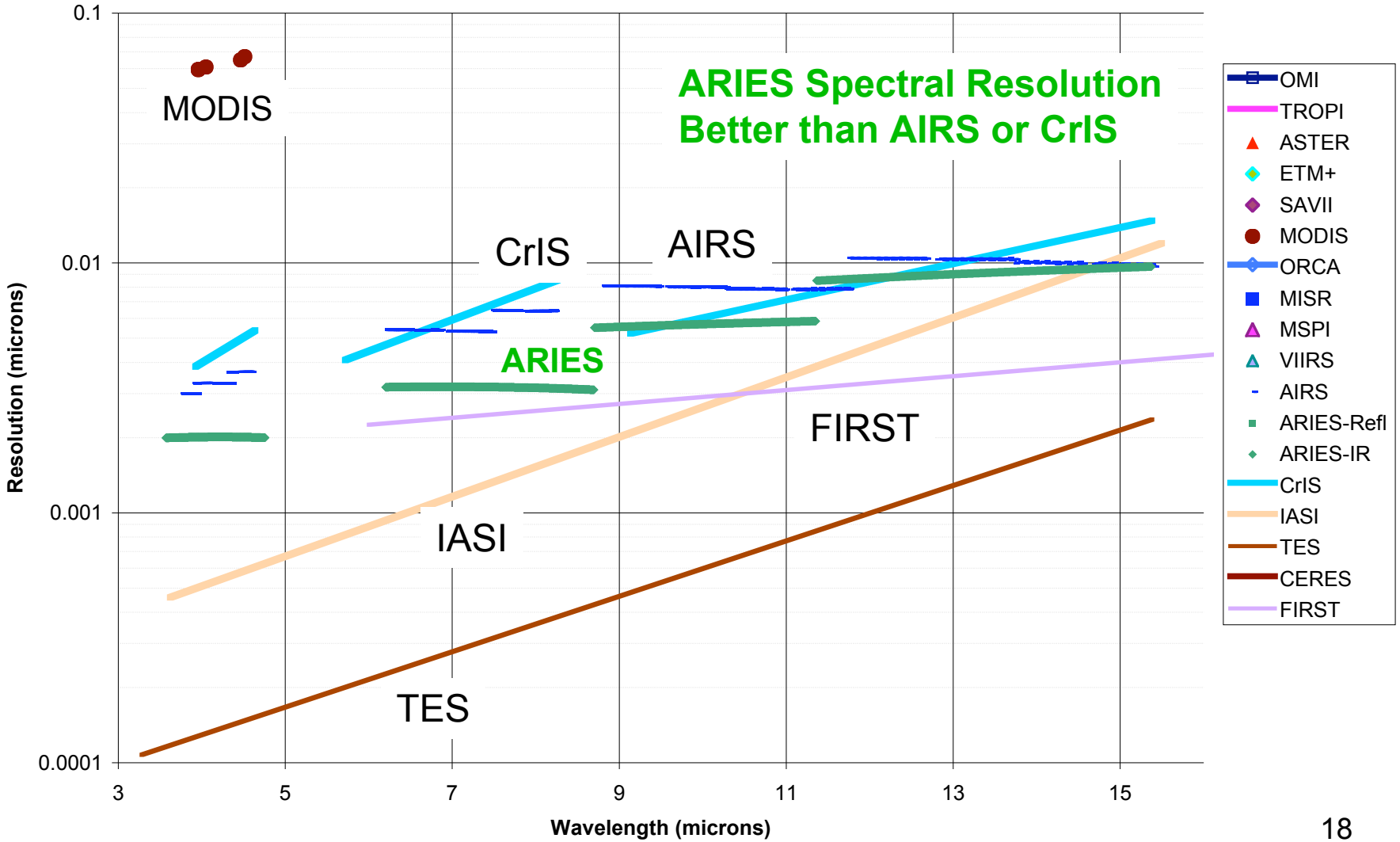
ARIES IR Spectral Resolution Better than AIRS or CrIS

Spectral Resolution For Spaceborne Optical Sensors



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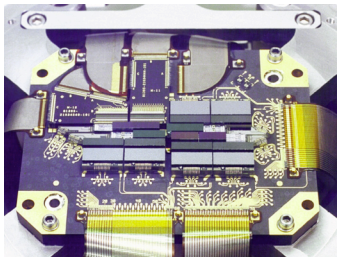
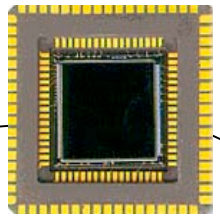
Technology Developments Since AIRS Allow ARIES Today

AIRS
BAE Systems
PV/PC HgCdte
17 modules
2 x ~180
100 x 50 um

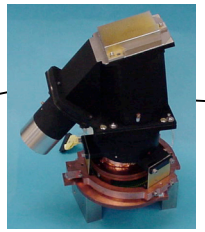


MODIS
Raytheon Vision Systems
PV/PC HgCdTe
4 FPAs
10 x ~10
400 x 400 um

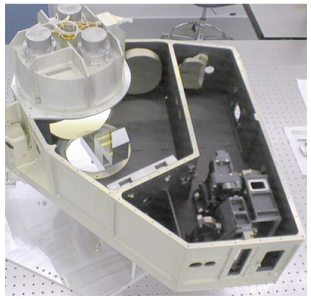
Rockwell
PV HgCdTe
256 x 256 x 6

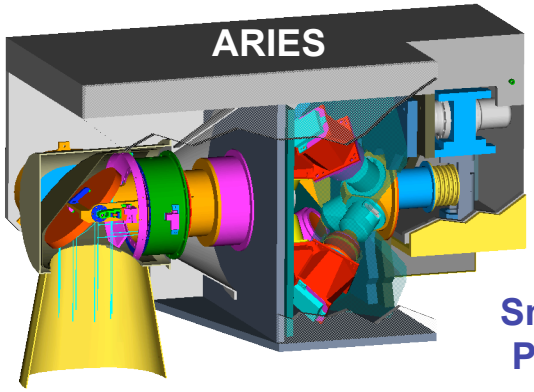


SIRAS IIP1
Refractive 16°
Grating Spectr

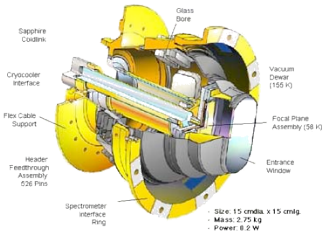


AIRS
Reflective 1.1°
Grating Spectr

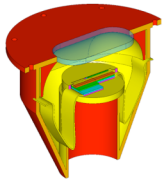




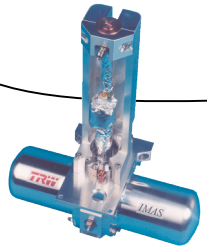
AIRS
Large Dewar



SIRAS IIP3
High Efficiency
Mini Dewars



NGST
Small Single
Pulse Tube
Cooler



AIRS
Large Dual Pulse
Tube Coolers

Developed under NASA Technology Development Programs (IIP, etc.)

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California Institute of Technology
Pasadena, California

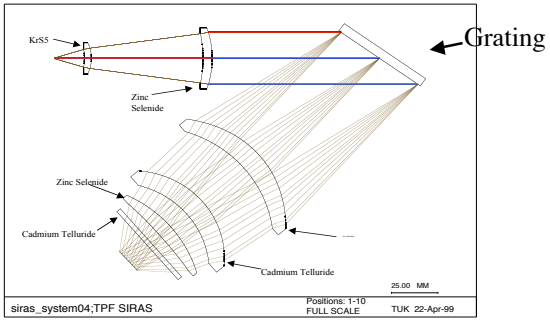
SIRAS IIP-1 ADVANCED GRATING OPTICS TECHNOLOGY

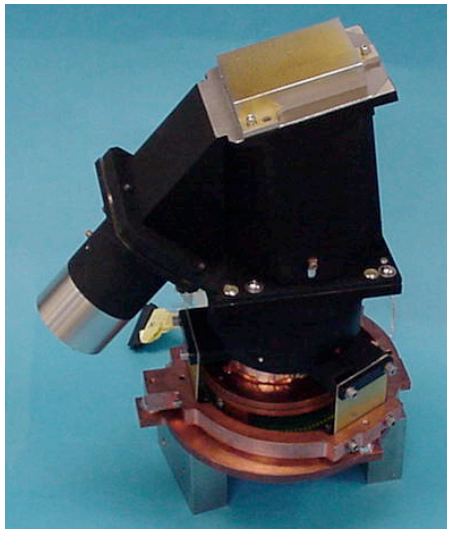
The Spaceborne Infrared Atmospheric Sounder (SIRAS) Spectrometer

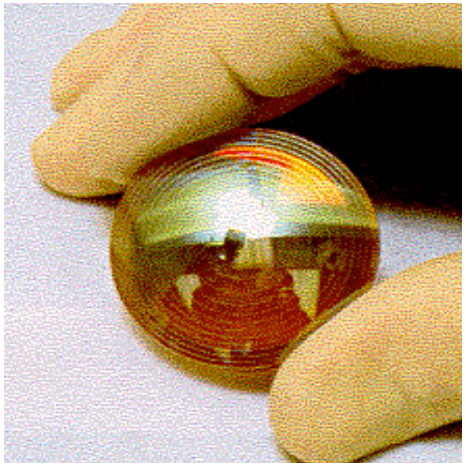
Developed under NASA Instrument Incubator Program in 2001

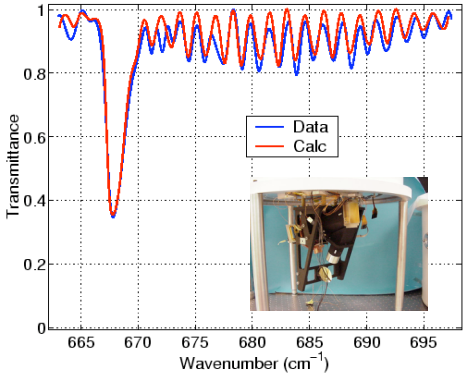
No Moving or Active Parts
Mass: 2kg
Size: 10 x 10 x 14 cm
Field of view X-Track: 16.2°
Pushbroom Operation
Spectral Resolution: >900 ($\lambda/\Delta\lambda$)
Number of Channels: 512 Each
4 Required for Full Spectral Range
Spectral Range: 12-15.4 μm

PI: Hartmut Aumann (AIRS IR Proj. Sci.)









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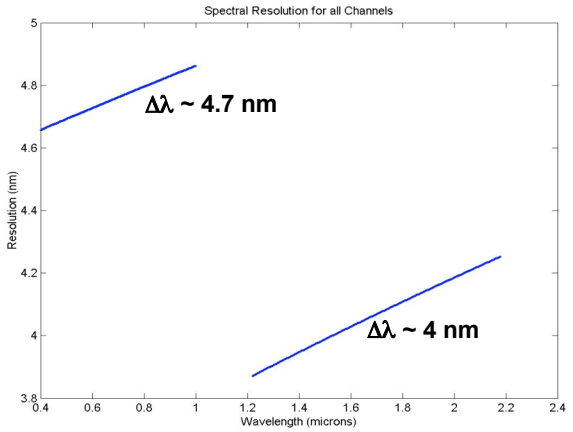
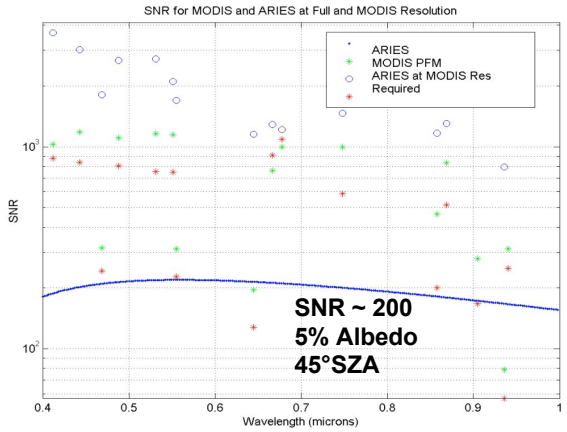
ARIES Exceeds AIRS and MODIS Performance

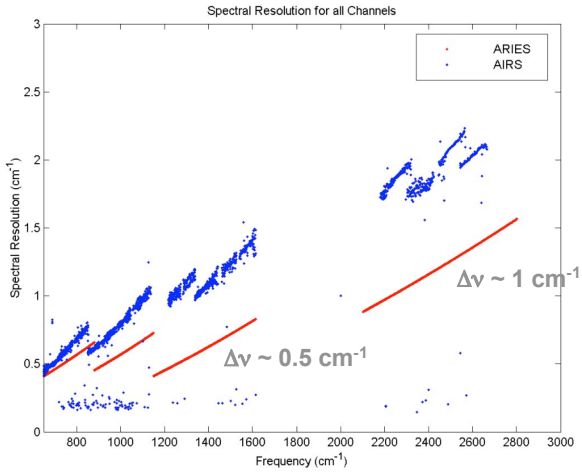
Vis/NIR/SWIR Spectral Resolution



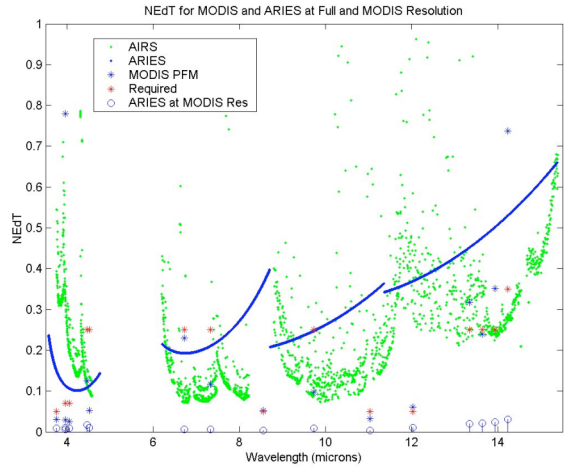
Vis/NIR SNR



IR Spectral Resolution



IR NEdT at 250 K



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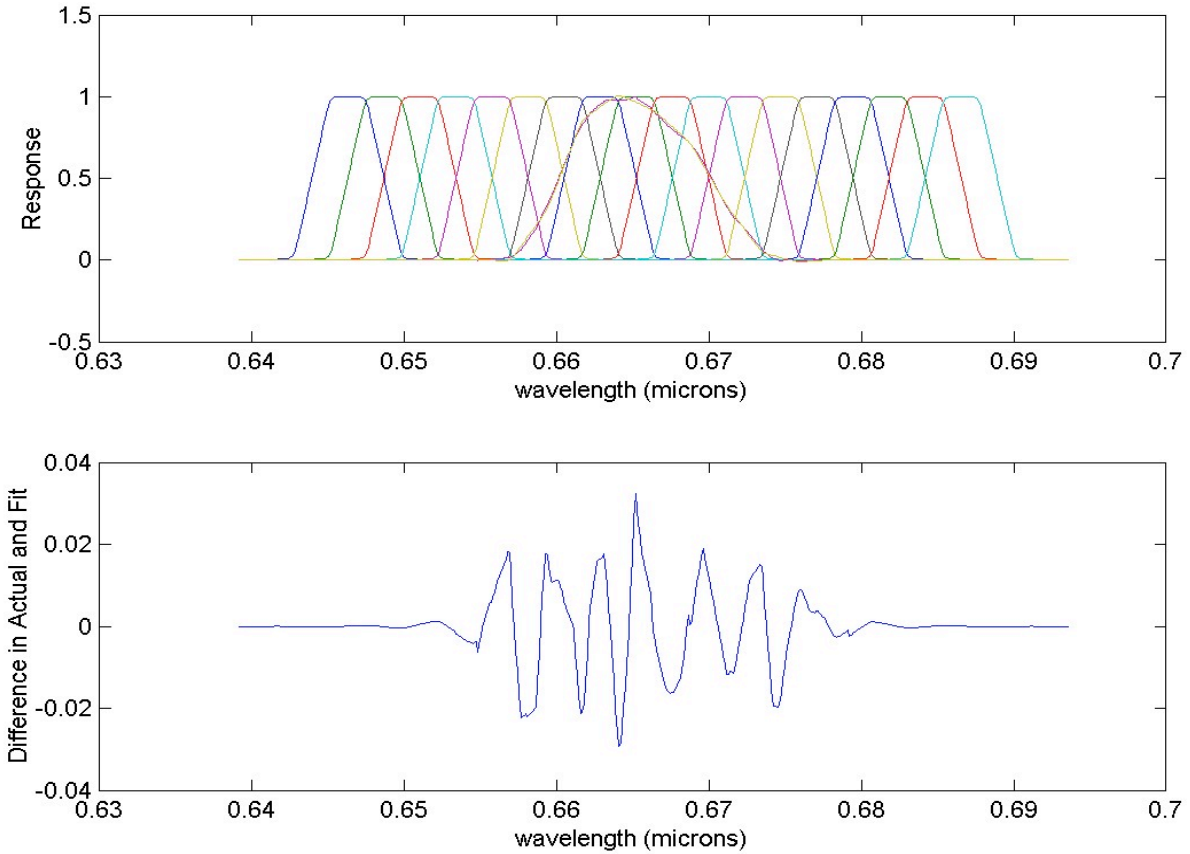
ARIES Synthesizes MODIS Band 13



Simulation Shows better than 4% Response Error Possible

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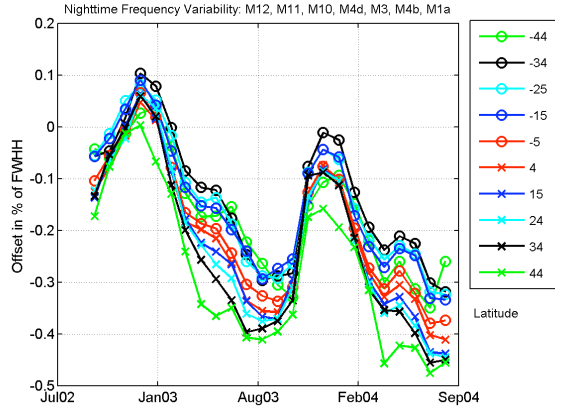
IR Calibration Based on AIRS

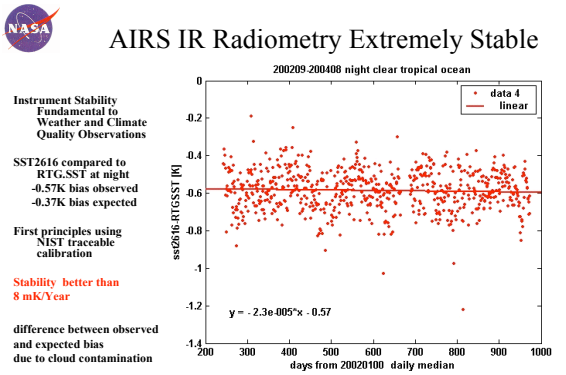
AIRS Frequencies Stable to <5 PPM Knowledge to < 1 PPM - L. Strow (UMBC)

ASL



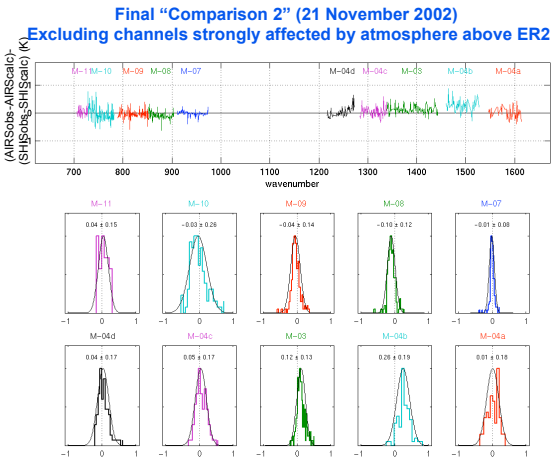
- **Full Aperture BB**
- **Full Aperture SV**
- **Active Thermal Control**
- **Extensive Pre-Flight Calibration**

AIRS Radiometric Performance: Stable to <8mK/Y – H. Aumann (JPL)

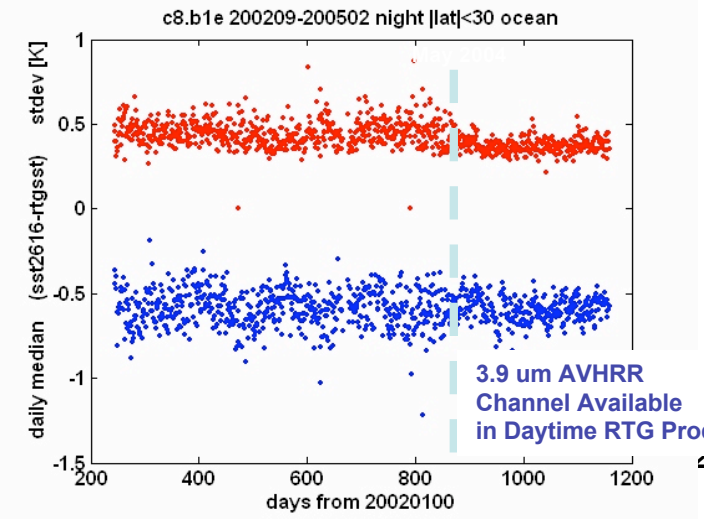


Aumann et al 2004 "Evaluation of AIRS Data for Climate Applications" SPIE 5570b Las Palmas September 2004

Scanning HIS Validates Rad Accy to 0.2K – H. Revercomb (UW)



AIRS Stable enough to detect RTG Improvement



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ARIES TRL is High

Subsystem	TRL	Comments
Scanner	9	Flight Proven on AIRS and MODIS
Telescope	9	Numerous similar reflective forms proven in space. Low Risk
Spectrometer	7, 9	Reflective Spectrometer in demonstration phase at JPL. Refractive Spectrometer Demonstrated on NASA IIP.
Focal Plane Assy	6, 9	Required Geometry Demonstrated on Ground, Similar Designs in Space
Dewar	9	Proven on AIRS
Cryocooler	9	Proven on AIRS and other programs
Blackbody	9	Proven on AIRS
Mechanical Systems	9	Proven on numerous flight missions
Electronic Subsystems	6, 9	Exact form proven in Lab, Similar Designs flown on AIRS and other Space Programs

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Conclusions

- ARIES takes imaging and sounding to the next level
  - Hyperspectral LWIR (3.4-15.4 μm) with Vis/NIR/SWIR Option
  - Higher Spatial Resolution IR (1km vs 13.5 km on AIRS)
  - Higher Spatial Resolution Vis/NIR hyperspectral (250 m)
- ARIES will be a breakthrough in regional weather prediction while improving upon the AIRS capability for global models
- ARIES high resolution will greatly enhance climate modeling by
  - relating regional processes to global processes
  - observing surface-atmosphere interactions
  - observing sources and sinks of major greenhouse gases
- ARIES Applications build on those of MODIS
  - ARIES can synthesize MODIS bands directly
  - All MODIS capability + Atmospheric Gases
- Experience of NASA Terra and Aqua Mission Teams will reduce risk and cost of ARIES as an operational system
- ARIES will support future needs of a very large user base
- Technology development from NASA IIP and NOAA HES makes ARIES possible today